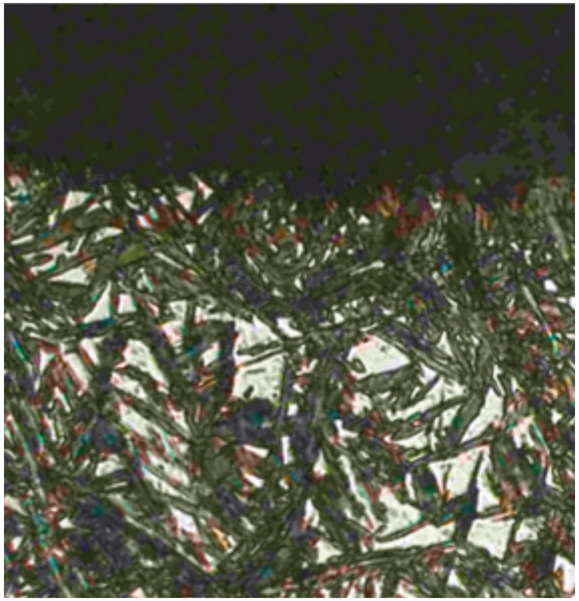
Bearing Steels

In a broad sense, bearing steels can be divided into classes intended for:

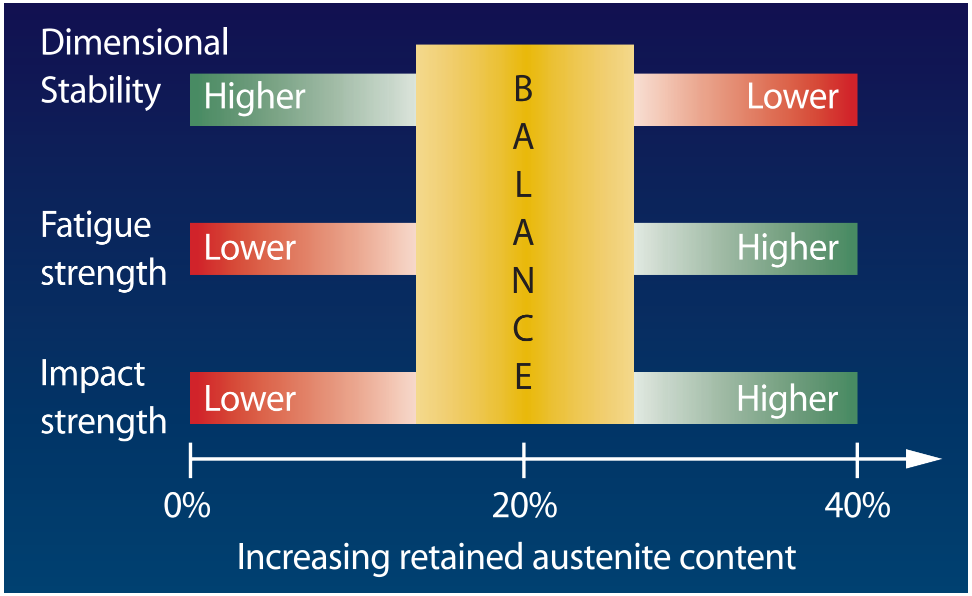
- normal service
- high-temperature service
- service under corrosive conditions.

Bearings for normal service conditions, a category that includes over 95% of all rolling-element bearings, are applicable when:

- Maximum temperatures are of the order of 120 to 150 °C although brief excursions to 175 °C may be tolerated
- Minimum ambient temperatures are about -50 °C
- The contact surfaces are lubricated with such materials as oil, grease, or mist
- The maximum Hertzian contact stresses are of the order of 2.1 to 3.1 GPa (300 to 450 ksi)



retained austenite



Dimensional stability

Fatigue; Low retained austenite content and fine austenitic grain sizes, which create a microstructure of finely dispersed retained austenite and tempered martensite, prevent nucleation of fatigue cracks, or retard fatigue crack initiation until very high stress levels are reached.

Impact: Impact strength is the measure of the ability of a steel to resist fracture when subjected to a sharp blow. Austenite is not only very tough, but also it has higher impact strength than martensite.

Traditionally, bearings have been manufactured from both high-carbon (1.00%) and low-carbon (0.20%) steels.

The **high-carbon** steels are used in either a through-hardened or a surface induction-hardened condition

Low-carbon bearing steels are carburized to provide the necessary surface hardness while maintaining other desirable properties in the core.

Both high-carbon and low-carbon materials have survived because each offers a unique combination of properties that best suits the intended service conditions.

For example, **high-carbon steels**:

- Can carry somewhat higher contact stresses, such as those encountered in point contact loading in ball bearings
- Can be quenched and tempered, which is a simpler heat treatment than carburizing
- May offer greater dimensional stability under temperature extremes because of their characteristically lower content of retained austenite

Carburizing steels, on the other hand, offer:

- Greater surface ductility (because of their retained austenite content) to better resist the stress-raising effects of asperities, misalignment, and debris particles
- A higher level of core toughness to resist through-section fracture under severe service conditions
- A compressive residual surface stress condition to resist bending loads imposed on the ribs of roller bearings and reduce the rate of fatigue crack propagation through the cross section
- Easier machining of the base material in manufacturing

High-Carbon Bearing Steels

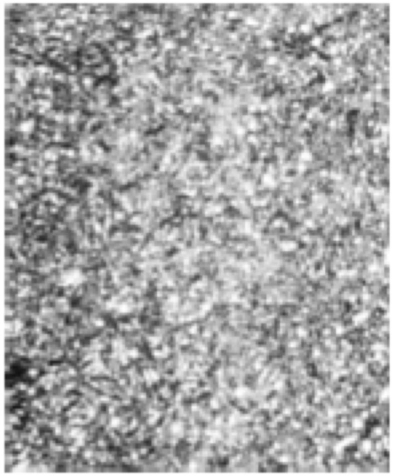
A typical microstructure of a hardened and tempered high-carbon bearing steel has a matrix of high-carbon martensite, containing primary carbides and 5 to 10% retained austenite.

The hardness throughout the section is typically 60 to 64 HRC.

The first three grades are listed in order of increasing hardenability; they are applied to bearing sections of increasing thickness to ensure freedom from nonmartensitic transformations in hardening.

Table 2 Nominal compositions of high-carbon bearing steels

Grade	Composition, %					
	C	Mn	Si	Cr	Ni	Mo
AISI 52100	1.04	0.35	0.25	1.45	. . .	. . .
ASTM A 485-1	0.97	1.10	0.60	1.05	. . .	. . .
ASTM A 485-3	1.02	0.78	0.22	1.30	. . .	0.25
TBS-9	0.95	0.65	0.22	0.50	0.25 max	0.12
SUJ 1[a]	1.02	<0.50	0.25	1.05	<0.25	<0.08
105Cr6[b]	0.97	0.32	0.25	1.52	. . .	. . .
SHKH15-SHD[c]	1.00	0.40	0.28	1.48	<0.30	. . .



Typical microstructure of a high-carbon through-hardened bearing component

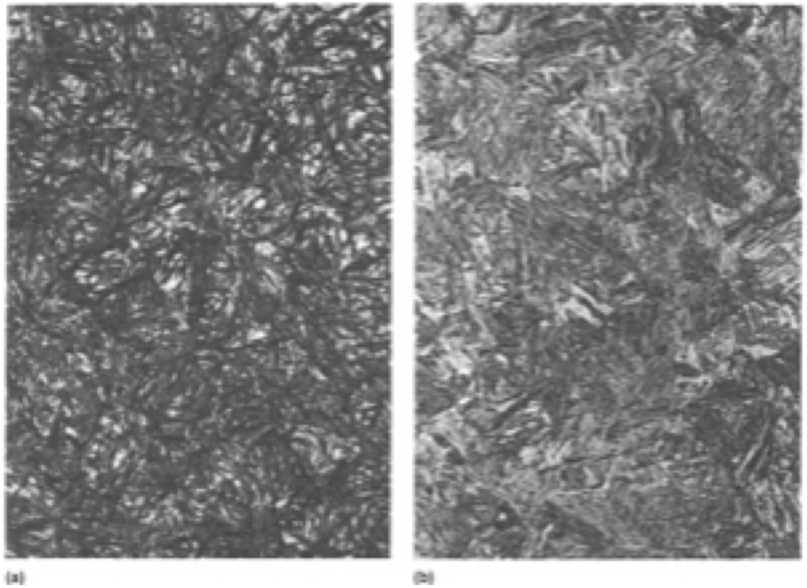
Carburizing Bearing Steels

The **case microstructure** consists of high-carbon martensite with retained austenite in the range of 15 to 40%.
Case hardness is typically 58 to 64 HRC.

In the **core** of carburized bearings, the microstructure consists of low-carbon martensite; it also often contains variable amounts of bainite and ferrite.
Core hardness may vary from 25 to 48 HRC.

Table 3 Carburizing bearing steels

Grade	Compositions, %					
	C	Mn	Si	Cr	Ni	Mo
4118	0.20	0.80	0.22	0.50	. . .	0.11
5120	0.20	0.80	0.22	0.80	. . .	. . .
8620	0.20	0.80	0.22	0.50	0.55	0.20
4620	0.20	0.55	0.22	. . .	1.82	0.25
4320	0.20	0.55	0.22	0.50	1.82	0.25
3310	0.10	0.52	0.22	1.57	3.50	. . .
SCM420	0.20	0.72	0.25	1.05	. . .	0.22
20MnCr5	0.20	1.25	0.27	1.15	. . .	. . .



Typical microstructures of carburized bearing components. (a) Case. (b) Core

The importance of a proper case microstructure to the ability of a bearing to resist pitting fatigue is illustrated in Fig. 7.

In particular, the presence of pearlite, resulting from a mismatch of quenching conditions and case hardenability, is shown to have a detrimental effect.

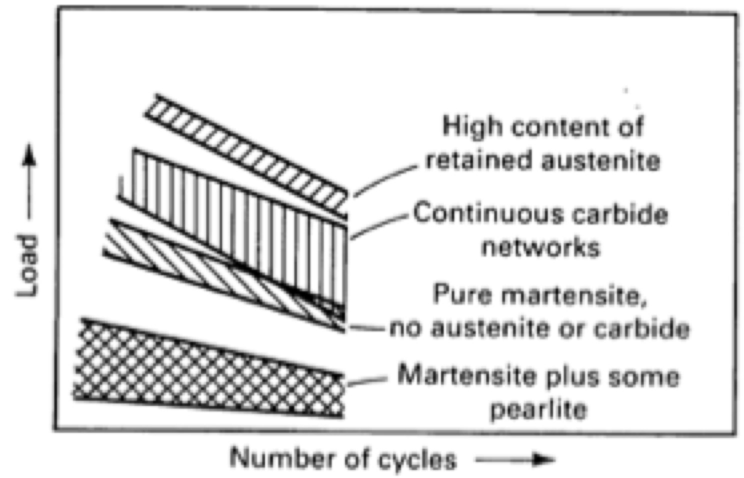


Fig. 7 Effect of surface microstructure on the shape of *S-N* curve for surface fatigue (pitting).

- Apart from a satisfactory microstructure, the single most important factor in achieving high levels of rolling-contact fatigue life in bearings is the cleanliness, or freedom from harmful nonmetallic inclusions, of the steel.

Bearing steels can be produced by one of these techniques:

- Clean-steel air-melt practices
- Electroslag remelting
- Air melting followed by vacuum remelting
- Vacuum induction melting followed by vacuum arc remelting

Special-Purpose Bearing Steels

When bearing service temperatures exceed about 150 °C, common low-alloy steels cannot maintain the necessary surface hardness to provide satisfactory fatigue life.

Therefore, specialized steels are often applied when these service conditions exist.

These steels are typically alloyed with carbide-stabilizing elements such as Cr, Mo, V, and Si to improve their hot hardness and temper resistance.

The listed maximum operating temperatures are those at which the hardness at temperature falls below a minimum of 58 HRC.

An important application of the high-temperature bearing steels is aircraft and stationary turbine engines.

Table 5 Nominal compositions of high-temperature bearing steels

Steel	Composition, %								Maximum operating temperature[a]	
	C	Mn	Si	Cr	Ni	Mo	V	Other	°C	°F
M50	0.85	...	...	4.10	...	4.25	1.00	...	315	600
M50-NiL	0.13	0.25	0.20	4.20	3.40	4.25	1.20	...	315	600
Pyrowear 53	0.10	0.35	1.00	1.00	2.00	3.25	0.10	2.00 Cu	205	400
CBS-600	0.19	0.60	1.10	1.45	...	1.00	...	0.06 Al	230	450
Vasco X2-M	0.15	0.29	0.88	5.00	...	1.50	0.5	1.50 W	230	450
CBS-1000M	0.13	0.55	0.50	1.05	3.00	4.50	0.40	0.06 Al	315	600
BG42	1.15	0.50	0.30	14.5	...	4.00	1.20	...	370	700

(a) Maximum service temperature, based on a minimum hot hardness of 58 HRC